Poster Abstract: Modular Architecture for Heterogeneous Sensor Networks

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Abstract— **Wireless sensor networks are becoming increasingly popular for wireless monitoring and automation of buildings and industrial processes. However, current network protocols are typically custom built for a specific application. Hence, the development of sensor networks is a time consuming and cost-inefficient activity. Moreover, the lack of support for heterogeneous networks and for advanced network functionality such as QoS and mobility prevents many developers to adopt wireless sensor technology. Therefore, in this paper we propose a universal, application independent architecture which is developed specifically for heterogeneous sensor networks.**

I. Introduction

The research in wireless sensor networks has known a tremendous boost in the last few years. Wireless sensor networks (WSNs) are becoming more and more widespread. Whereas sensor networks were originally used mainly for monitoring purposes, new applications such as process and asset monitoring, disaster intervention and wireless building automation are rapidly emerging [1]. Considering these facts, it is clear that future sensor networks will impose more diverse requirements on the different sensors and not all of these sensors will be capable to fulfill these requirements. Whereas the first sensor networks consisted of a large number of homogeneous nodes, additional computing power or functionality will be required in some nodes. Sensor networks are thus evolving into heterogeneous networks.

Even though many new applications for sensor networks are designed, there exist currently no protocol framework which is widely applicable. Current work mostly focuses on scalable and energy-efficient protocols. Each application thus requires a specific developed protocol stack. The ZigBee Alliance [2] is defining application profiles for specific applications. However, these profiles do not taken into account the heterogeneity of the network. Although this research is very valuable for the development of sensor networks, there is at present no optimized architecture in which these solutions can be implemented. Thus, developing sensor networks currently comes at a great developments cost, impeding the growth of sensor networks and hindering the cooperation between different sensor networks

II. Universal Modular Framework

A. Motivation

The evolution of sensor networks as described above clearly shows the need for an optimized generic, application independent solution that accounts for the network heterogeneity. Furthermore, energy efficiency will remain one of the key drivers in the research for optimizing wireless sensor networks.

Several authors have pointed out that cross-layer optimization is a very promising strategy in order to reduce the energy consumption [3], [4]. Many networking aspects interact with multiple layers, such as QoS, security, transmission power, etc. As such, the exchange of information between different layers can enhance the performance of the wireless network.

We have defined an architecture where functionality is divided in modules that interact with each other. This modular design has several key advantages:

- Duplication of functionality is prevented;
- Due to the possibility of information exchange more energy-efficient protocols are supported;
- Heterogeneity is promoted: additional or more advanced modules can be added to a node according to it's capabilities;
- Through the replacement of modules, it is easy to adapt to changing network conditions and future developments.

The use of modular protocols is thus a very promising approach for sensor networks.

B. Proposed framework

A schematic overview of the proposed framework is shown in figure 1. One can clearly see the modular layer structure that takes care of the functionalities of the MAC and network layer. The middleware layer is designed to implement functionality that requires a strong interaction between application layer and network layer. An example is data-aggregation which, depending on the application, can be as simple as calculating the average of several data sets or realize complex data processing. Next, the physical layer is also a separate layer as the properties of this layer largely depend on the design of the hardware. Finally, in order to allow for better optimization, a shared cross-layer database forms a generic interface for the exchange of cross-layer parameters.

As stated above, heterogeneity is one of the major characteristics of future sensor networks. In order to cope with this heterogeneity, more and different modules can be added in the nodes depending on their capabilities. To avoid a myriad of nodes that each support a different set of functionalities we propose to use different classes of nodes by defining profiles. Based on their capabilities, we could e.g. define 3 types of

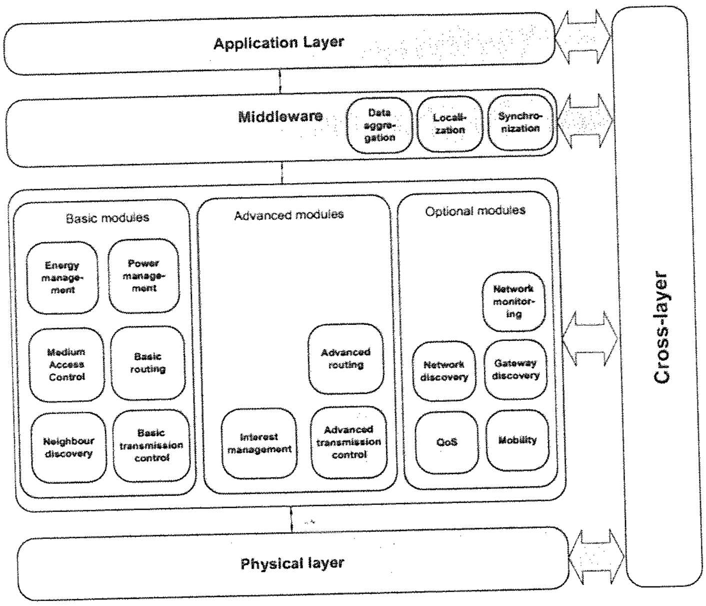

Fig. 1. Proposed universal modular framework for sensor networks

nodes: **lightweight nodes**, **advanced nodes** and **computing nodes**. The lightweight nodes have very limited resources and will only support the basic functionalities, hence only the basic modules will be implemented. The advanced nodes are more powerful. They will also implement the advanced functionality which is needed for a scalable and energy efficient WSN. The computing nodes are the most powerful and have a much larger battery capacity (e.g. connected to the power grid) and computing power. They will be equipped with optional modules that are not necessary for a proper operation of the network, but they offer an added value for more advanced applications, e.g. QoS or mobility support.

C. Example modules

We illustrate these principles with some example modules.

- Each node will have a basic module taking care of the basic transmission control. This module will handle the segmentation, error correction and retransmission. More advanced nodes can also be equipped with an advanced module which can buffer packets for batch transmission. Finally, computing nodes can take care of optional transmission control functions, such as in-order-delivery and congestion control.
- Routing in lightweight nodes can be as simple as sending all generated data packets to a nearby advanced or computing node. As advanced and computing nodes have full-routing capabilities, they can create routes based on criteria such as hop distance or remaining battery power.
- Some modules are only implemented in computing nodes, such as QoS and network monitoring. These services can be offered to the application even if only a small subsets of the nodes are computing nodes. For example, a computing node can provide QoS by examining incoming packets, adjusting their priority to fulfill delay requirements or duplicating them to a second route to fulfill reliability constraints.

D. Challenges when designing functional modules

Developing protocols in a modular way requires adjustments on the approach of designing network protocols. Some challenges when designing functional modules are the following:

- One has to determine the parameters to be exchanged in the different modules. The performance increase should at least compensate for the additional complexity introduced by the cross-modular interaction.
- There is a need to identify which parameters need to be optimized at design-time and which at run-time.
- When designing modules, the interaction between different modules should be thoroughly examined. For example, when choosing the next hop node, the decisions of the routing module (shortest path) may interfere with decisions of the energy management module (hop with most remaining battery power). To avoid uncontrolled competition, a decision algorithm should be developed.

III. Conclusion and Future Work

Current sensor networks have several key requirements that can not be supported using the traditional layered protocols. Support for energy-efficiency and heterogeneity has to be implemented at an architectural level, not only in isolated protocols that do not take the layer interaction into account. Furthermore, in order to promote interoperability of protocols and to reduce the cost of application development for sensor networks, there is a strong need for an application independent solution.

We proposed a universal applicable framework that, due to it's modular design is exceptionally fitted to support energy-efficient protocols and heterogeneous networks.

Future work will focus on the design of modular protocols and the possible methods for information exchange. Also, the feasibility of the framework will be experimentally validated in a hardware test bed.

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